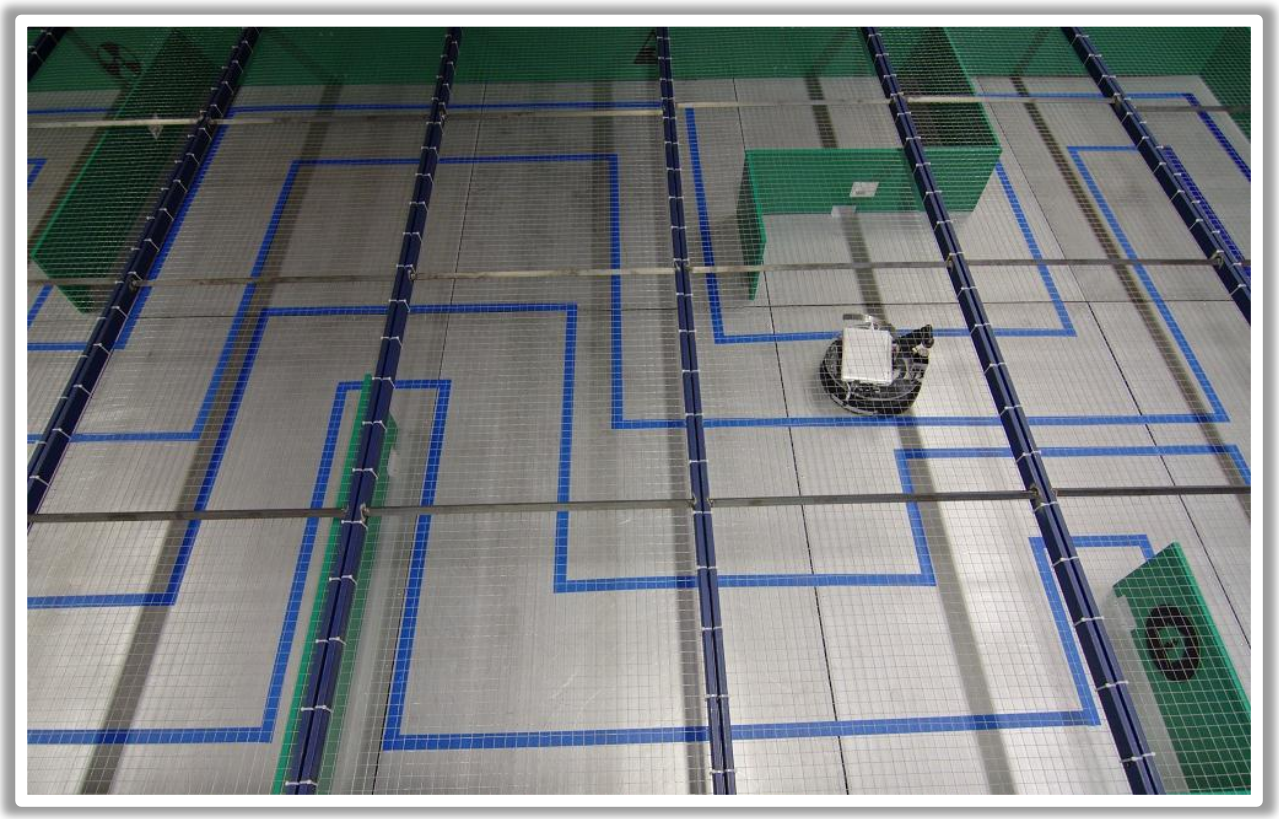
UNIVERSITY OF TECHNOLOGY SYDNEY

IROBOT RIG
LABORATORY USER GUIDE

VERSION 2.1



UTS remotelabs

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Revision History

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2.0	30/05/2012	Initial Release	Luke Cogar
2.1	30/05/2012	Fixed description in section 1.2, misc typographical corrections.	Luke Cogar
2.2	04/06/2012	Fixed descriptions, removed supercded notes.	Luke Cogar

1 Introduction

1.1 Remote Laboratories

Remote laboratories enable students to access physical laboratory apparatus through the internet, providing a supplement to their studies and existing hands-on experience. Students carry out experiments using real equipment, but with much greater flexibility since access can occur from anywhere and at any time. Their interaction with the remote equipment is assisted by the use of data acquisition instrumentation and cameras, providing direct feedback to students for better engagement.

Traditional engineering laboratories require students to be physically present in order to work with equipment, which may limit student flexibility. Conversely, remote laboratories let students work in their own time and even repeat experiments for better learning outcomes.

Of course students cannot actually touch and feel the equipment in a remote laboratory, but they can still perform most other tasks relevant to their learning. Sometimes, separation from potentially hazardous equipment is preferable from a safety point of view.

Due to the increased use of remote operation in industry, where machinery and entire plants are often controlled from a distant location, students may directly benefit from learning how to remotely control equipment. Furthermore, remote laboratories provide the opportunity to access a wider range of experiments as costly or highly specialised equipment may not be locally available. This presents the opportunity to share laboratory facilities between institutions.

Significant research and pilot studies have been undertaken in Australia and by several groups around the world into the educational effectiveness of using remote laboratories. These studies have consistently shown that, if used appropriately in a way that is cognizant of the intended educational outcomes of the laboratory experience, remote laboratories can provide significant benefits.

Indeed, multiple research studies have demonstrated that whilst there are some learning outcomes that are achieved more effectively through hands-on experimentation (e.g. identification of assumptions, specific haptic skills), there are other learning outcomes that are achieved more effectively through remotely accessed laboratories (e.g. processing of data, understanding of concepts).

Engineering students are able to access the iRobot Rigs to help them record, analyse and compare data from a range of sensors and develop, simulate and test localisation and mapping algorithms.

1.2 iRobot - The Rig Apparatus

The iRobot rig was designed to allow students to explore the concepts of teleoperation of robots, accuracy of sensors, localisation and mapping.

Using a web-based interface, students are able to remotely control the robot and observe its movements, record data provided by the different sensors, compare said sensor data. Additionally, students can test control algorithms developed in the robot simulation software "Stage" by using the robot control software "Player" to control the iRobot create.

Each iRobot Rig consists of the following main components:

- 1 x Electrical Supply System
- 1x Maze
- 1x iRobot Create
  - *1x Laser Rangefinder*
  - *1x Webcam or Visual Rangefinder*
  - *1x Control Computer*
  - *1x UTS Remote Labs Power Management PCB*
  - *1x UTS Remote Labs Voltage Regulation PCB*
  - *1x Li-ION Battery*

Additionally, each iRobot rig is monitored by an IP camera with pan and tilt functions – providing an overview of the maze. The camera can operate in "manual" mode, where the user selects which portion of the maze to view – or "auto" mode, where the robot's position is automatically tracked and the camera moved to the appropriate viewpoint.

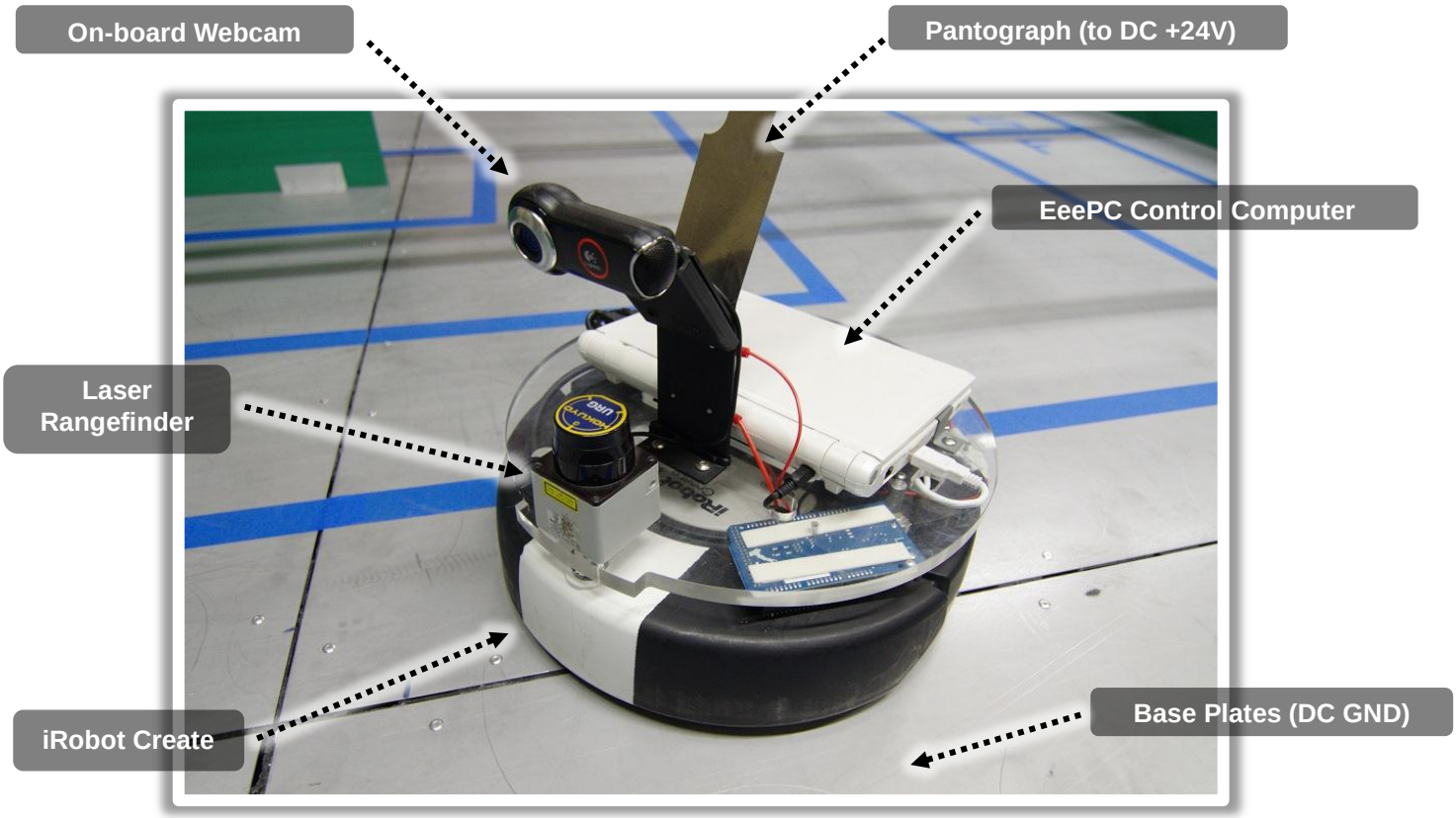


Figure 1: iRobot Rig.

2 Rig Specifications

2.1 Electrical Supply System

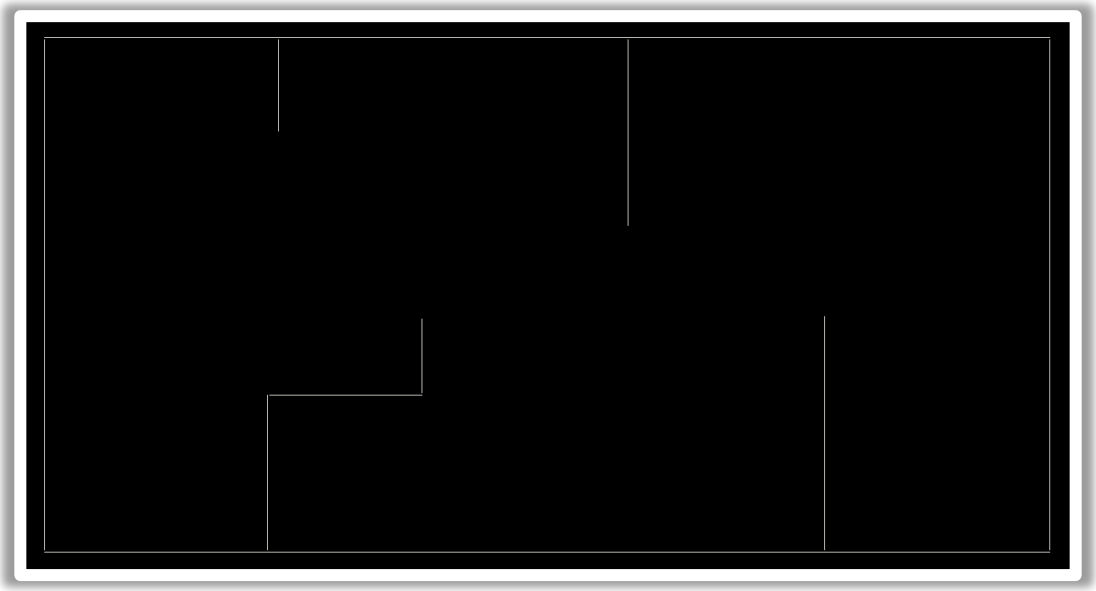
The iRobot rig is powered by a fixed 24V DC supply capable of providing 150W of power. The electrical supply system consists of a set of 12 “tiles” that are composed of an inter-locking plastic under layer and hot-dipped zincanneal coated steel upper layer.

Adjacent “tiles” are coupled by a conducting cable – with the whole layer acting as the electrical ground plane of the system.

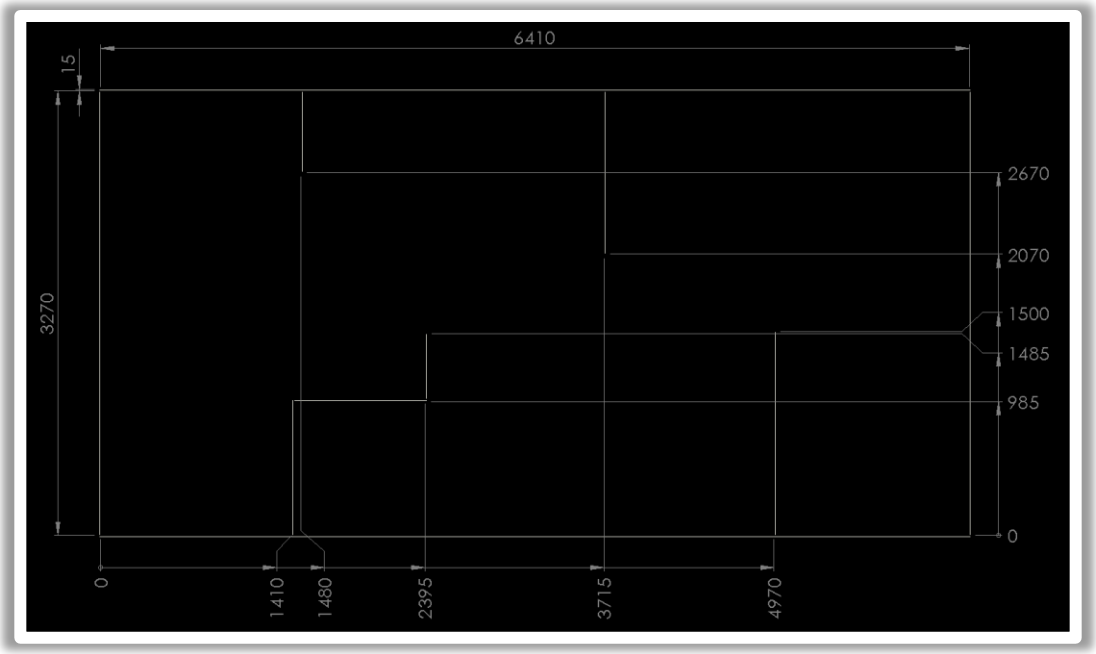
Additionally, there are a set of 7 upper panels, consisting of a steel frame and steel mesh – again connected by a conducting cable to one another. These upper tiles act as the positive (24V) plane of the system. The robot gets power from two “pantographs” which interface with the tiles and panels.

2.2 Maze

Between the upper and lower tiles forming the electrical supply system is a wooden maze – which acts as the operating space for the iRobot.



The dimensions are shown below. All dimensions are taken from the internal walls, units are mm.



2.3 iRobot Create

The robotics platform used in the rig, and the source of the rig's title, is the iRobot Create. The iRobot create is essentially the same as the popular house-cleaning robot, made by iRobot, the Roomba – the major exception is that the Create no longer has a vacuum unit, and is controllable and monitor able through the "Create Open Interface".

The iRobot Create has a two-wheel differential drive system, wheel odometers, bump, cliff and wheel-drop sensors, infrared sensor and serial communications port.

Modifications have been made to the iRobot Create in the form of an upper and lower "pantograph" – these are metal plates that interface with the electrical supply system, providing power to the power management system, voltage regulation circuit & battery.

2.4 Laser Rangefinder

To complement the on-board sensors, a Hokuyo URG-04LX laser rangefinder is attached to the front of the iRobot Create. The laser rangefinder allows users to retrieve extremely accurate sensor data over a wide field of view and with a large number of data points.

The rangefinder operates on the principle of phase-shift measurement by modulating the amplitude of the emitted light and measuring the phase shift between the emission and its reflection. Specifications for the unit are provided below:

Laser Rangefinder Specifications	
Manufacturer:	Hokuyo Automatic Co., Ltd.
Model Number:	URG-04LX
Operating Principle:	Phase-shift
Detection Area:	240°
Maximum Detection Distance:	5600mm
Accuracy:	20-1000mm: ±10mm 1000-4000mm: ±1% of measurement
Resolution:	1mm
Scan Angle:	0.36°
Interface:	USB
Supply Voltage:	5VDC
Power Consumption:	500mA

2.5 Webcam / Visual Rangefinder

The iRobot Create is also equipped with an on-board webcam that provides a near real-time video feed of the operating environment from the perspective of the robot. The webcam used is a Logitech Quickcam Pro 9000.

The webcam can also operate as a visual rangefinder, whereby during "logging" mode, the camera feed is analysed to identify the walls – then transformed using the "Inverse Perspective Mapping" algorithm in order to estimate the distance to them. The specifications for the webcam are given below:

Webcam Specifications	
Manufacturer:	Logitech
Model Number:	Quickcam Pro 9000
Field of View:	75°
Effective Focal Length:	2mm
Maximum Resolution:	1600 x 1200 (2MPx)
Interface:	USB

2.6 Power Management, Voltage Regulation & Battery

The iRobot Create has an on-board power management system as well as voltage regulation and backup battery. The system was designed in-house at UTS as a unique and innovative solution to providing constant power to the robot and its associated hardware.

As the robot moves around the maze, there may be brief interruptions to the electrical supply due to the upper and/or lower pantographs on the robot not making perfect contact with the conduction surface(s).

The power management system automatically switches between the standard electrical supply (24V) and the battery (14.8V) when this occurs. In order to ensure that all components have the required supply voltage at all times, adjustable (3-13V) step-down switching voltage regulators that maintain a fixed output voltage are used.

Additionally, in order to provide a constant 14.8V output to the iRobot – a step-up/step-down voltage regulator is used, this ensures that regardless of the electrical supply voltage (i.e. if the battery voltage drops over time) that the robot supply voltage is constant.

All in all – the power management, voltage regulation and battery system result in the iRobot rig being usable 24 hours, 7 days a week with no interruptions to the user experience. Specifications are given below:

Power Management & Voltage Regulation Circuit Specifications:	
Manufacturer:	UTS Remote Labs
Max Battery Charge Current:	3A
Battery Charge Cutoff Voltage:	16.8V
iRobot Supply Voltage:	14.8V
EeePC Supply Voltage:	9.5V
Laser Rangefinder Supply Voltage:	5V

Battery Specifications	
Manufacturer:	Sanyo
Model Number:	4/UR18650FM
Nominal Voltage:	14.8V
Capacity:	2.6Ah / 38.5 Wh

2.7 More Information

A specification pack containing more information on the hardware used will be released at a later date as a downloadable archive (.zip) file located on the session page for each rig.

3 Rig Control Software

Once you have been allocated to a rig – you should be presented with the rig control software. This is an HTML5 web interface that allows you to control the robot in three different ways – manually, autonomously (data logging) or by uploading code.

Note: If you have issues using the Rig Control Software interface, please update to the latest browser. The latest version of each major browser is recommended (e.g. Internet Explorer, Firefox, Chrome).

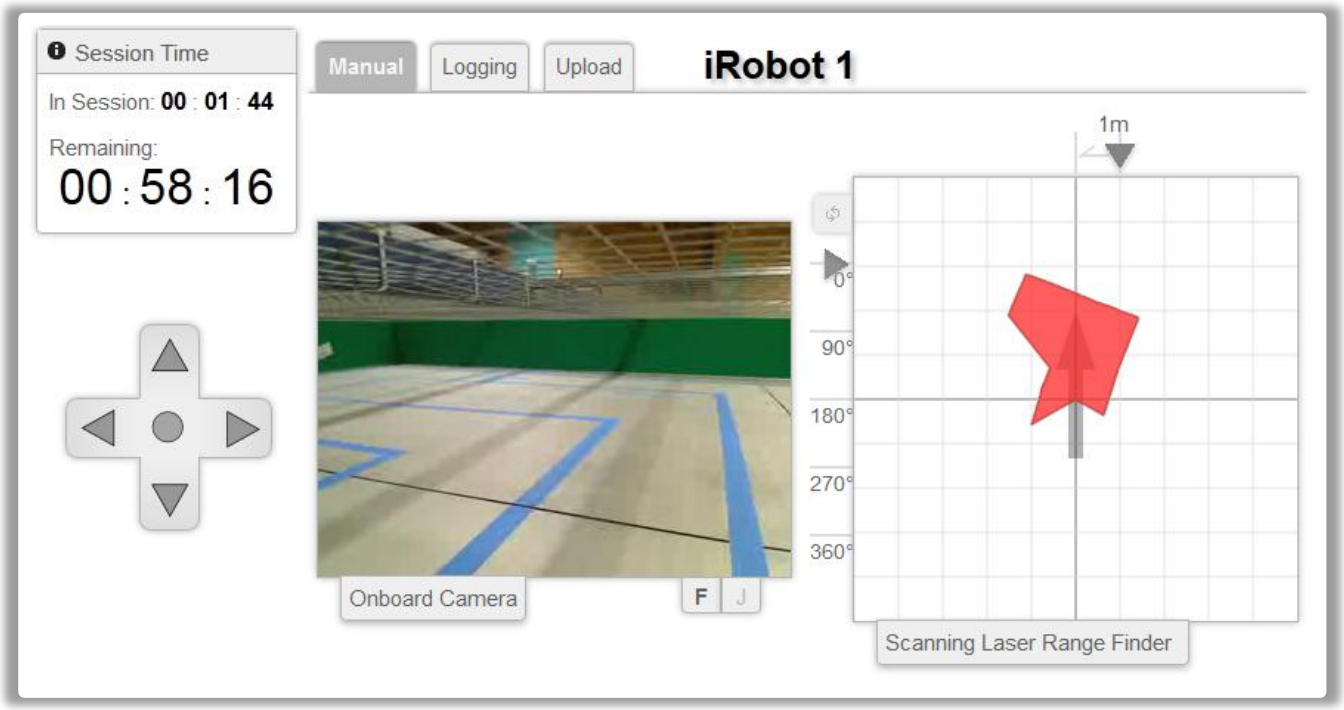


Figure 2: *Rig Control Software with the system operating in manual mode.*

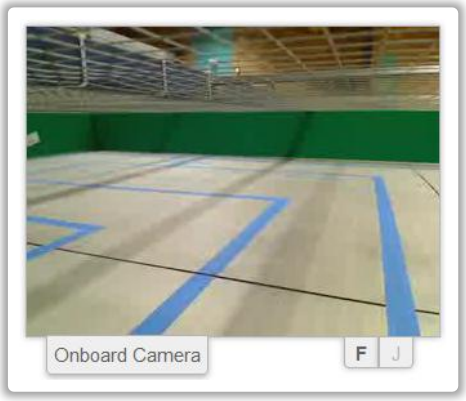
3.1 Data Display

The rig control software displays numerous sources of data in real-time. Familiarise yourself with the display and relevance of this data by reading through the sections below.

3.1.1 Manual Mode

3.1.1.1 On-board Camera

In manual mode, the on-board camera is shown – allowing the user to see the maze from the perspective of the robot. This can be used to relate sensor data to the "real" world and understand the benefits and limitations of using non-visual sensing systems.



3.1.1.2 Laser Rangefinder

In manual mode, the user is also presented with a graphical representation of the laser rangefinder data. The user is able to adjust the scale (i.e. increase/decrease the size) and plot relationship (i.e. rotate the view) by dragging the arrows on the X and Y axes respectively. Additionally, you can click and drag the plot to translate it/generate an offset.

The space between the return and the origin for each respective point are infilled in red, allowing the user to easily identify obstacles such as walls.

By default, the laser rangefinder displays data in a robot-centric view, that is, data is displayed as the robot sees it. By clicking the small "**rotate**" icon to the top left of the display, the user can **toggle** between this default **robot-centric view** and a **world-centric view**.

In the world-centric view, data is displayed from a fixed reference point (as if you were looking down on the robot's location, but always pointing in the same direction). The arrow then indicates the robot's orientation in the world, and the data displayed is relative to this absolute fixed reference point.

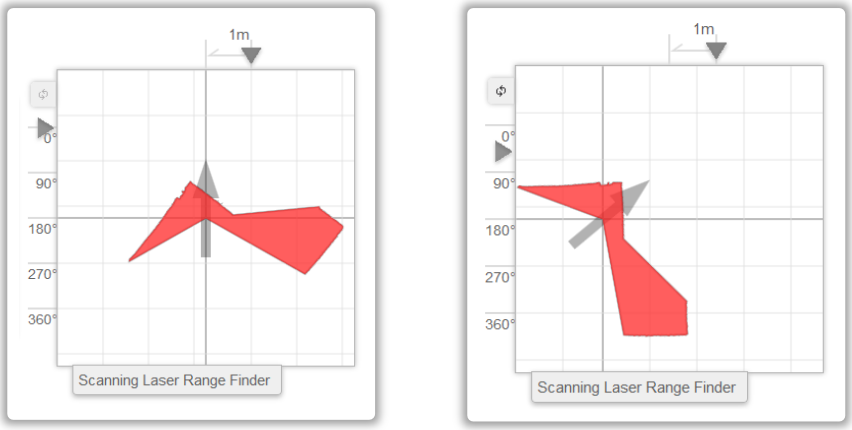


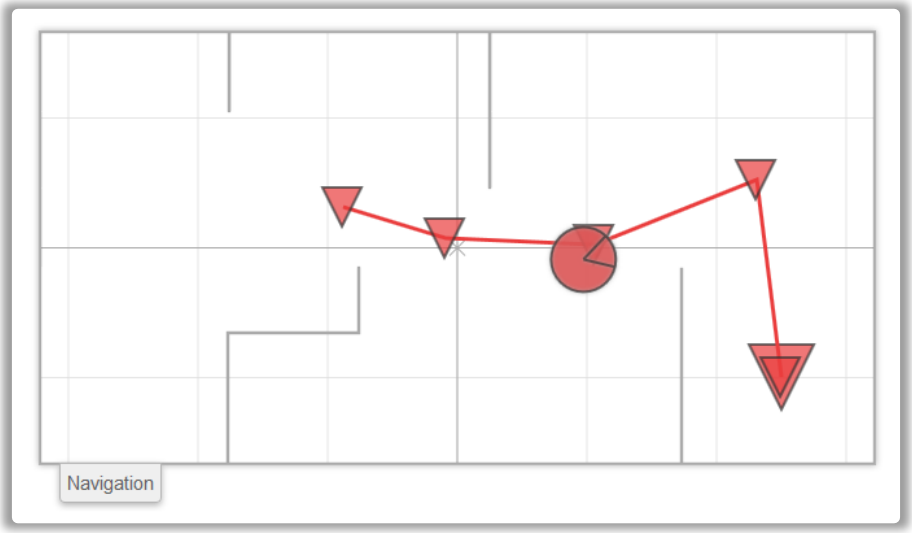
Figure 3: The laser data in robot-centric view (left) & world-centric view with scaling & offset (right).

3.1.2 Logging Mode

3.1.2.1 Navigation Map

In logging mode, the user is presented with a representation of the map and the iRobot Create. When the robot has localised, its representation will turn red – and it will begin path planning and driving between various waypoints in the maze.

These waypoints are represented by small red triangles, with the goal or final waypoint having a larger red triangle overlaid. The path planned for waypoint traversal is represented by a solid red line.



3.1.3 All Modes

3.1.3.1 Overhead Camera

In all modes, the overhead camera view is displayed – allowing you to see the location of the iRobot Create within the maze. You can also gain an understanding of the limitations of “local” sensor systems – i.e. those attached to the robot.

3.2 Overhead Camera Control

The overhead camera can be controlled in two different ways depending on the needs of the user. The default control method is that of “Manual” control – whereby the user has to click and drag the red square (representing the camera Field of View) around the maze diagram repeatedly, so as to follow/find the robot.

The second control method is that of “Automatic” control – whereby the rig control software uses the robot’s position (once known) to automatically move the camera as the robot moves, attempting to keep the robot in the Field of View square at all times.

Users can switch between modes at any time by clicking the “Manual” or “Auto” buttons on top of the camera control panel.

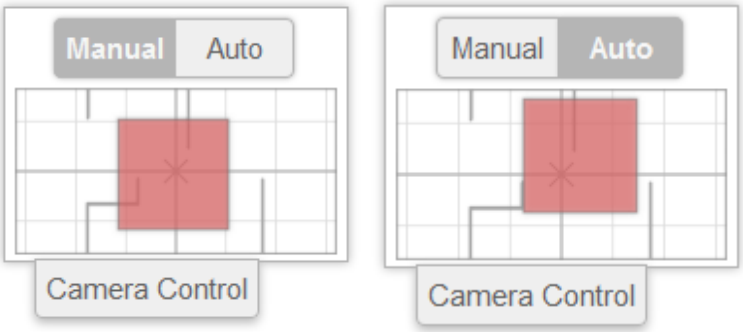


Figure 4: *Camera control panel, showing selection of Manual mode (left) and Auto mode (right).*

3.2.1 Manual Control

As mentioned above, in manual control mode, the user must manually **click and drag** the red Field of View square around the maze diagram so as to follow/find the robot manually. The images below show the relationship between the camera Field of View and the actual overhead camera image.

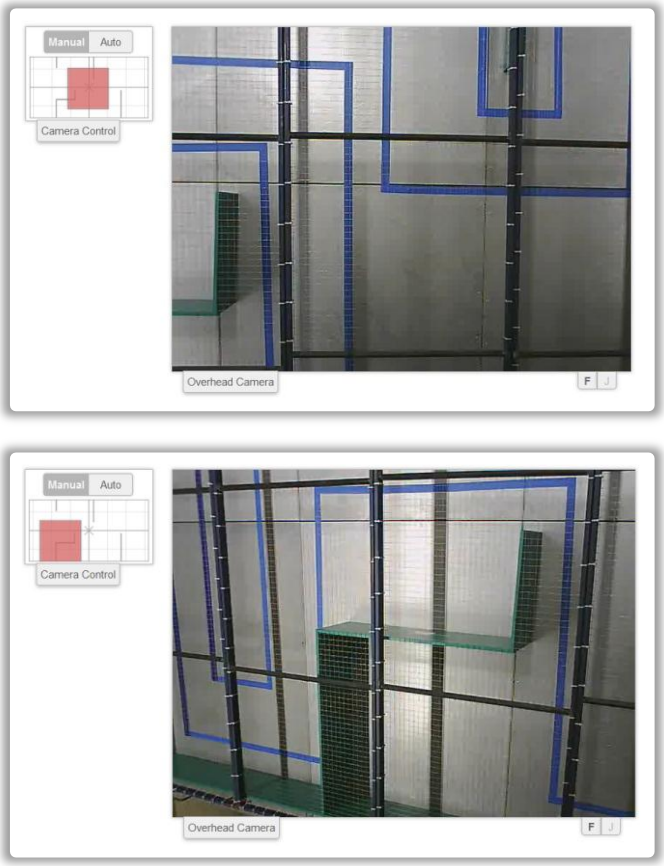


Figure 5: *The Field of View square centred at the origin (top) then moved to the lower-left corner (bottom)*

3.2.2 Automatic Control

In automatic control mode, the rig control software keeps track of the robot's position (once known) and moves the camera automatically so that the robot is kept within the Field of View square at all times.

The system is fairly new and there may be some optimisations that need to be made to improve performance. If you note any irregularities or performance issues, please be sure to contact support.

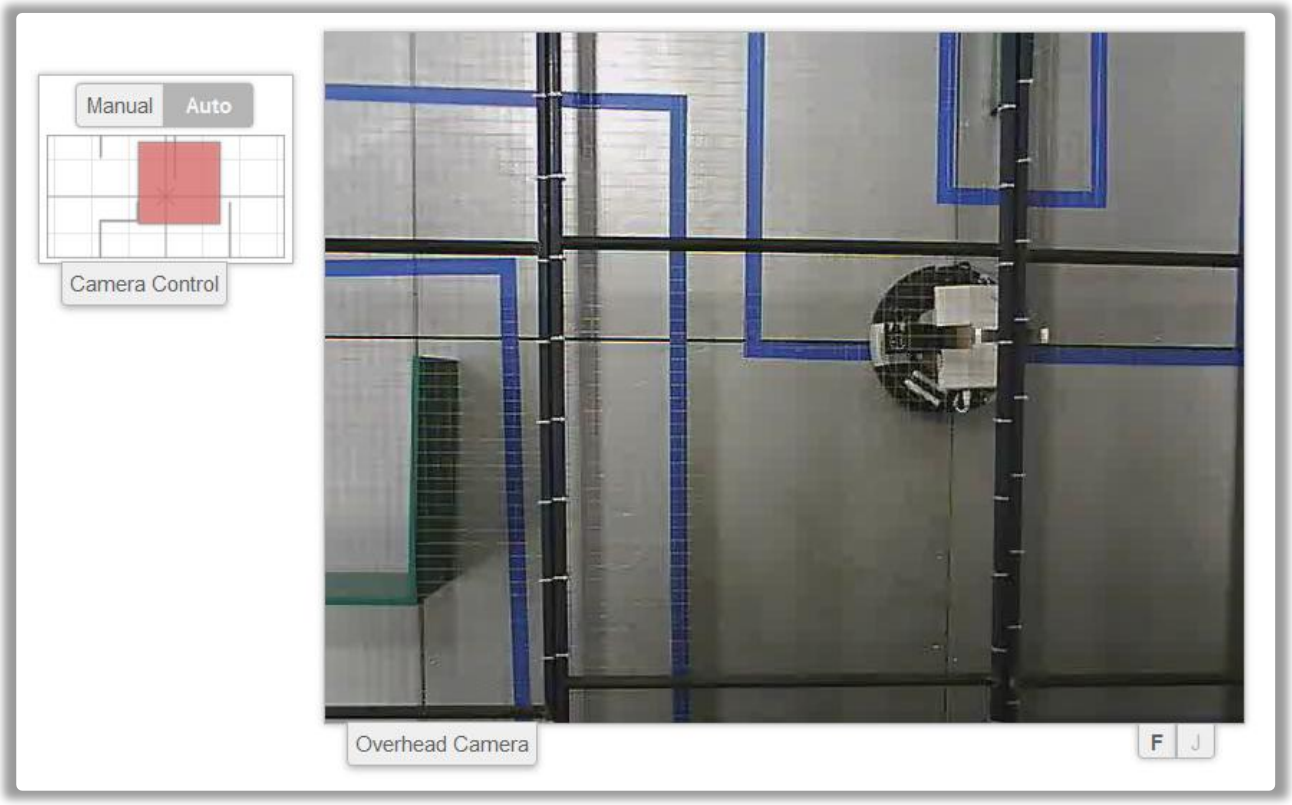
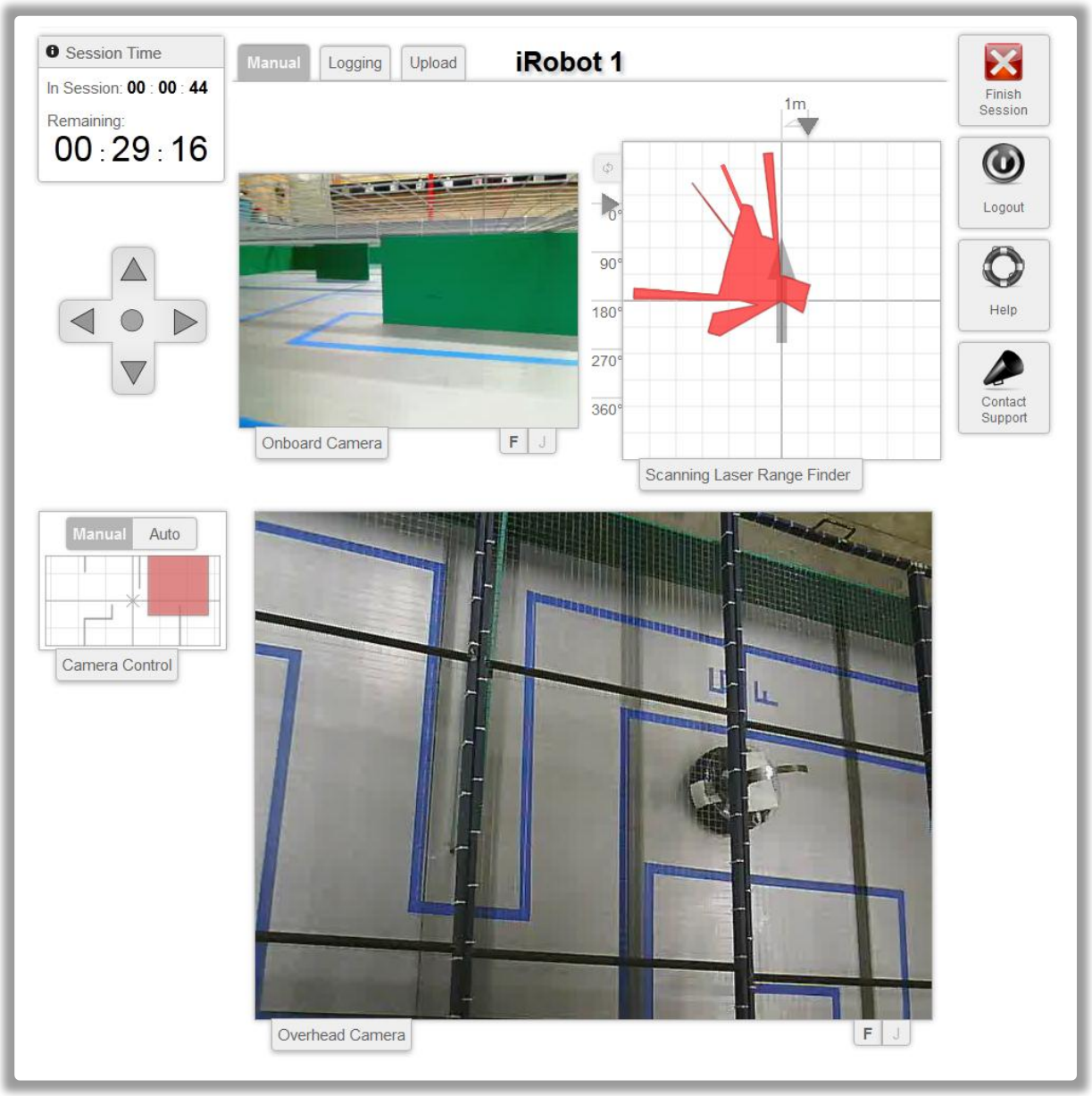


Figure 6: *The robot being tracked automatically by software, with the camera position adjusted accordingly.*

3.3 Manual Mode

When the iRobot rig is in manual mode, you are in control. You are provided with the on-board camera, overhead camera and laser rangefinder data. A screenshot of this mode is shown below:



For movement, you can either use the **directional pad** on the rig control software page (to the left of the camera view) by clicking (or optionally clicking & holding) on the appropriate direction you want to move.

Other options include using the **WSAD keys** on your keyboard, or ↑/↓/←/→ arrows. You can navigate the maze using any combination of the on-board camera, laser rangefinder or overhead camera.

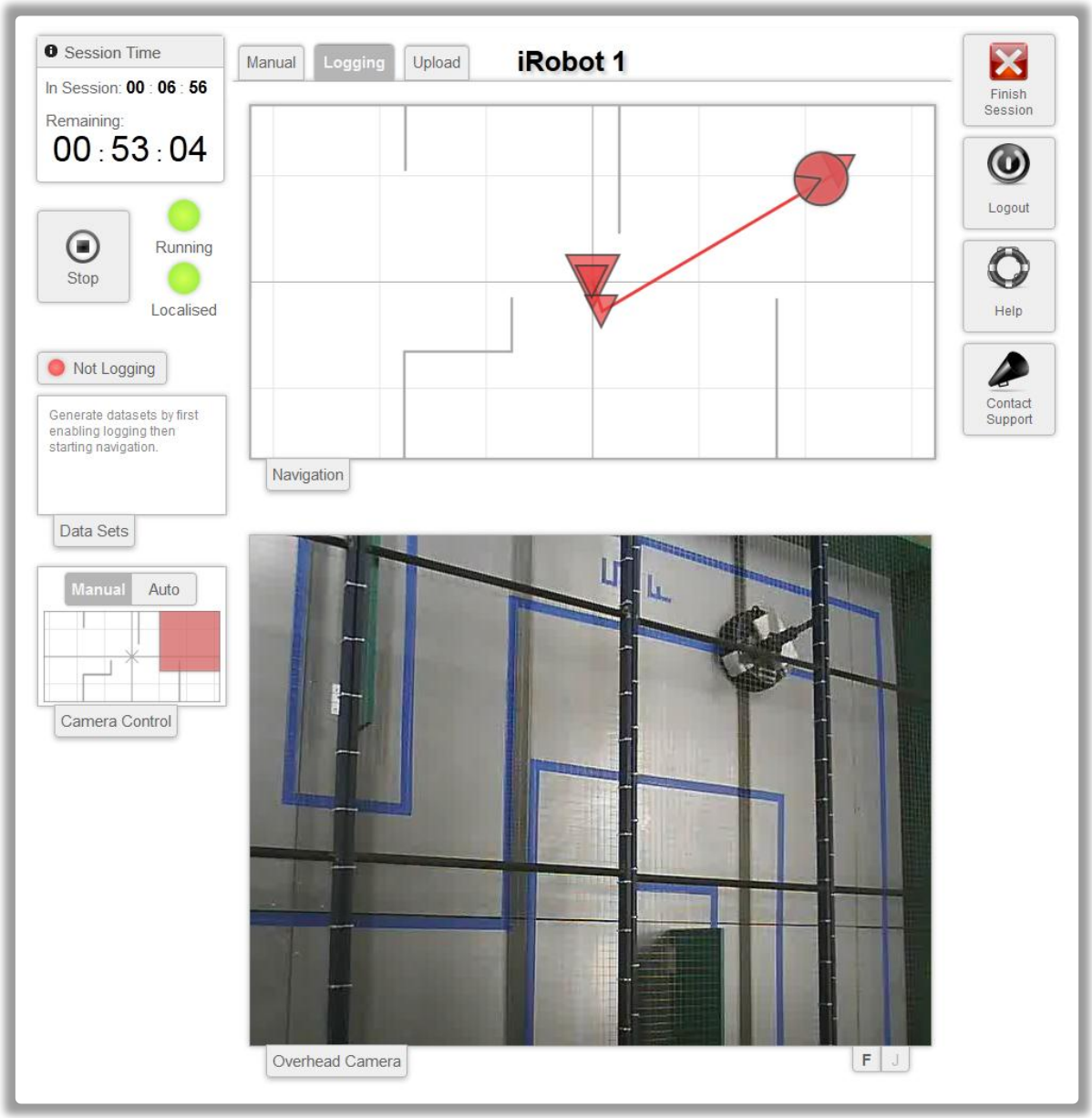
Key	D-Pad	Command*
W / ↑	▲	Drive the robot forwards.
S / ↓	▼	Drive the robot backwards.
A / ←	◄	Turn the robot to the left.
D / →	►	Turn the robot to the right.

* Command direction is from the reference frame of the iRobot Create.

Take care to avoid obstacles in the maze such as walls. Additionally, be sure to account for any time delay between sending a command to the robot and receiving sensor data.

3.4 Logging Mode

When the iRobot rig is in logging mode, the robot operates autonomously. You can ***enable*** data logging at any time, regardless of whether the robot is "started" or not – however data will not actually be logged until the robot is "started". A screenshot of this mode is shown below:



By clicking the "**Start**" button to the left of the navigation map, the robot will attempt to localise itself and if successful, begin driving between various "waypoints" throughout the maze autonomously.

If the robot fails to localise, please see **"Section 5.1- The robot fails to localise- how can I fix this?"** for steps to take to resolve the issue. Once you have recorded enough data, you can either stop logging or stop the robot.

Key	D-Pad	Description
W / ↑	▲	Drive the robot forwards.
S / ↓	▼	Drive the robot backwards.
A / ←	◄	Turn the robot to the left.
D / →	►	Turn the robot to the right.

4 Rig Data Acquisition

Users are able to save data from the iRobot Create and its associated sensors. Follow the procedures below carefully.

4.1 Turning Data Logging On/Off

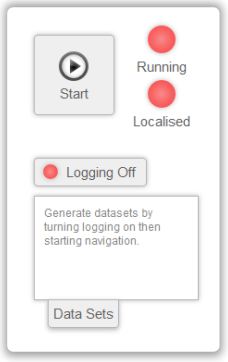
Whilst in the "Logging" mode, enable logging by toggling the "**Logging Off**" button by clicking it – such that it changes to say "**Logging On**" with a green indicator.

Now, click the "**Start**" button, the "**Running**" indicator will turn green. You then need to wait for the robot to localise, once it has done so, the "**Localised**" indicator will turn green. If the robot fails to localise, see **"Section 5.1- The robot fails to localise- how can I fix this?"**

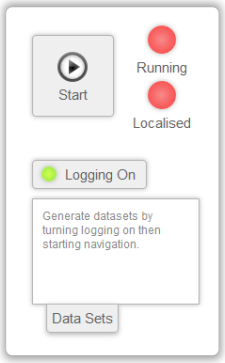
If all is well - the robot will begin driving around autonomously with the system logging data from the iRobot Create and its sensors as it drives around the maze.

To stop logging, toggle the "**Logging On**" button by clicking it so that it shows "**Logging Off**" with a red indicator - optionally you can also click the "**Stop**" button so that the robot stops driving around before you change modes or begin a new logging session.

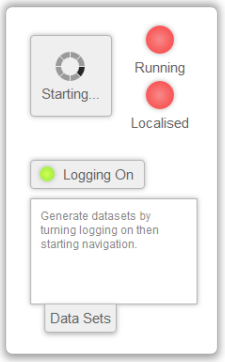
Note that each time a new "run" is started, a new dataset will be generated.



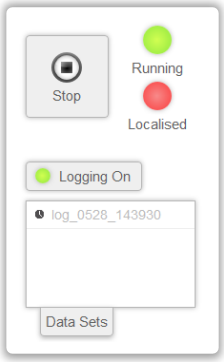
Step 1: Locate the "**Start**" button and "**Logging Off**" button.



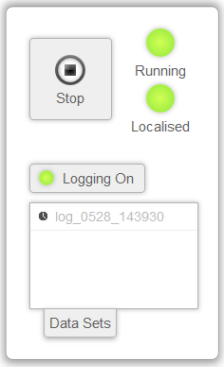
Step 2: Toggle the "**Logging Off**" button so that it turns green and shows "**Logging On**".



Step 3: Click the "**Start**" button and wait for the system to start.



Step 4: The status should now show "**Running**" with a green indicator.



Step 5: Wait for the robot to localise – it will show "**Localised**" with a green indicator once it has.

NOTE: The robot will automatically stop driving autonomously and stop logging data after it has reached 7 goals. If you need to collect more data for analysis purposes, simply re-run the exercise by following the steps above.

4.1.1 Log File Contents

The downloaded dataset zip contains a log file and on-board camera snapshots taken every second whilst logging has been turned on – the filenames of the images correlate to the time stamps of the **laser,1** interface & index.

The log file is formatted for use within Player/Stage. The table below shows the interface names and indexes and describes what the data is.

Interface	Index	Description
`position2d`	0	iRobot Create odometer data.
`position2d`	1	ND (nearness diagram) driver data.
`position2d`	2	Wavefront driver data.
`laser`	0	Laser rangefinder data.
`laser`	1	Camera laser data.

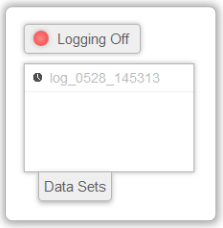
4.2 Downloading Logged Data

The logged dataset is saved as a zip file and is downloadable either during your rig session or after your rig session has concluded.

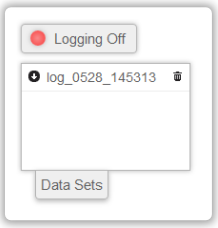
4.2.1 During a Rig Session

If you wish to download your logged dataset during a rig session, you must first ensure that logging is off. You must then wait a moment for the data to be processed – the log filename will appear light grey, with a small clock icon to the left and be un-clickable during this time.

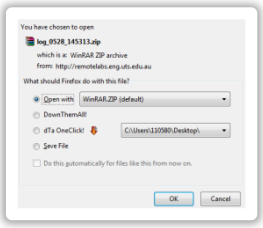
Once processed, the log filename will turn black and display a download icon to the left as well as a trash icon to the right. Simply click the filename to download the file. A browser-specific download window should then appear - be sure to click "**Save File**" or similar in this window to save the file in an appropriate location on your computer.



Step 1: Ensure you turn logging off. Your log file will now begin to be processed and will appear in grey text with a small clock icon to the left.



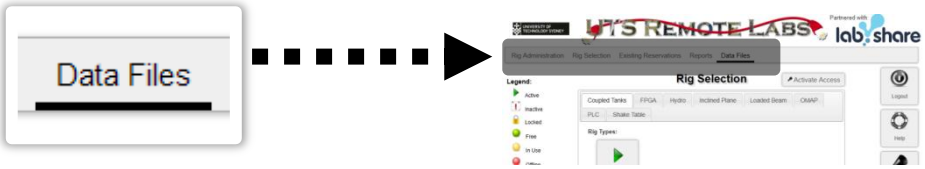
Step 2: Once processed, your log file will appear in black text with a download icon to the left and a trash icon to the right. Click the log filename to download the file.



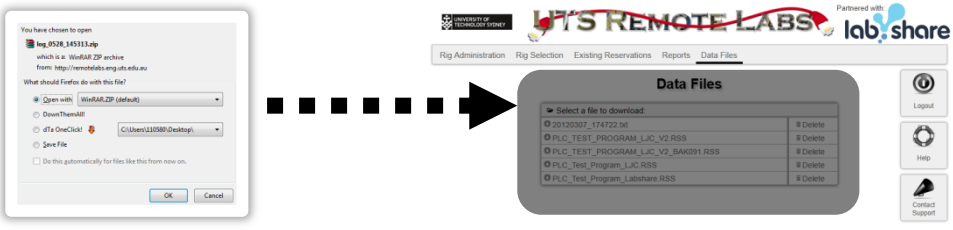
Step 3: Once clicked, a browser-specific download window should appear. Be sure to click "**Save File**" or similar in this window and to save the file to an appropriate location on your computer.

4.2.2 After a Rig Session

If you have completed a rig session previously, and logged data, you are able to retrieve the saved files by **clicking the** "**Data Files**" **heading** on the UTS Remote Labs website.



A list of previously saved data files should appear, to download & save the file to your computer, **click the zip file title** *(e.g. log_0528_145313.zip)*. **If the file does not appear – it may still be processing**.



After clicking the zip file title, a browser-specific download window should appear - be sure to click "**Save File**" or similar in this window to save the file in an appropriate location on your computer.

5 FAQ & Troubleshooting

5.1 The robot fails to localise- how can I fix this?

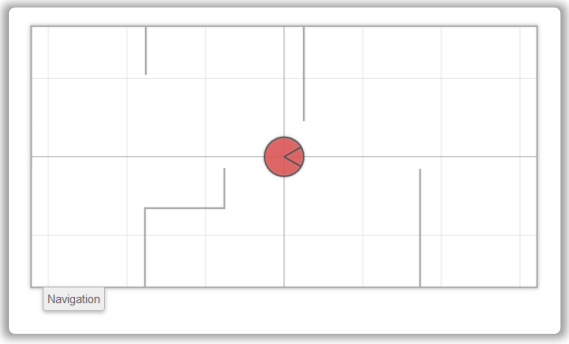
Occasionally, the robot may fail to localise in the “Logging” mode. This can happen for several reasons – such as if it is too close to a wall, located tightly in a corner or too close to a goal.

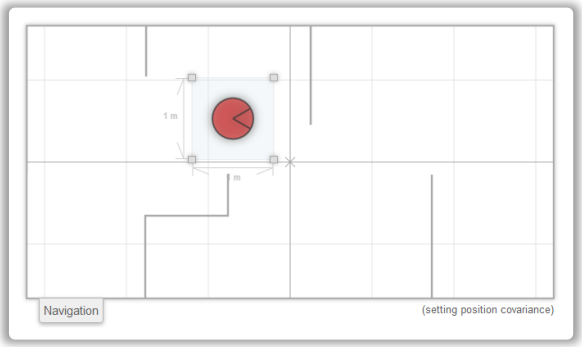
Should this happen, you have two main options. Firstly- you can switch back to “manual” mode, drive the robot to a different location and then switch back once more to “Logging” mode and begin the process again. This is the simplest method.

Alternatively, you can follow the steps below. Given the robot position shown below, we will attempt to re-localise by giving the robot a better idea of where it is:

- **Step 1 – Set Position & Position Covariance:** On the navigation map, click and drag the robot position representation icon to another position on the map, close to where it actually is – in our case, we will move it up and to the left.

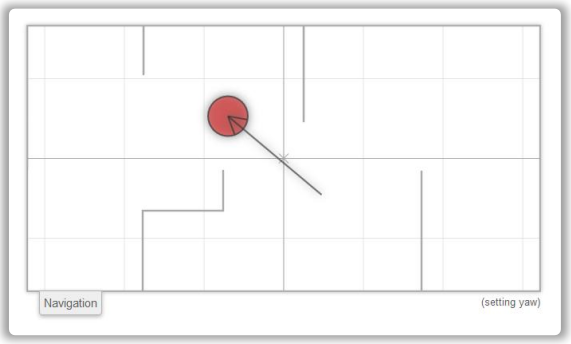
  Once you have moved it, you can adjust the covariance by dragging the square markers at each corner or you can click elsewhere on the map to go to the next step.



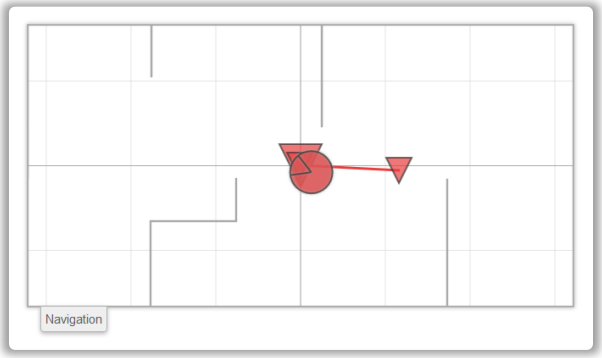


- **Step 2 – Set Yaw & Yaw Covariance:** A line should now appear for you to set the yaw angle of the robot. In our case, the robot is pointing down and to the right, so we will set the yaw at a similar (approximation) of this angle – once you have an approximate yaw, click on the map.

  Once the yaw is set, we must now adjust the yaw covariance, you can do this by dragging the square markers at the edge of the arc or you can click elsewhere on the map to go to the next step.



- **Step 3 – Wait & See:** Within a few moments the robot should (hopefully) localise and begin driving around autonomously. In our case – success! It has localised and is now navigating between waypoints by itself. If you are not successful at localising – try the steps again or try the manual method.



5.2 Hardware Limitations

The following hardware limitations apply to the rig – care should be taken to avoid mistaking real phenomena as faults and the limitations should be observed when analysing data obtained from the rig.

5.2.1 iRobot Create Movement

In manual mode, in order to provide an easy method of control– the movement of the iRobot Create has been defined in a discrete manner. When the robot is commanded to drive forward, it does so at a fixed velocity of 0.5 m/s and when commanded to turn, does so at a fixed radial velocity of 0.5 rad/s.

Commands are issued for however long the user holds down the key on their keyboard or however long the user clicks the D-Pad on-screen.

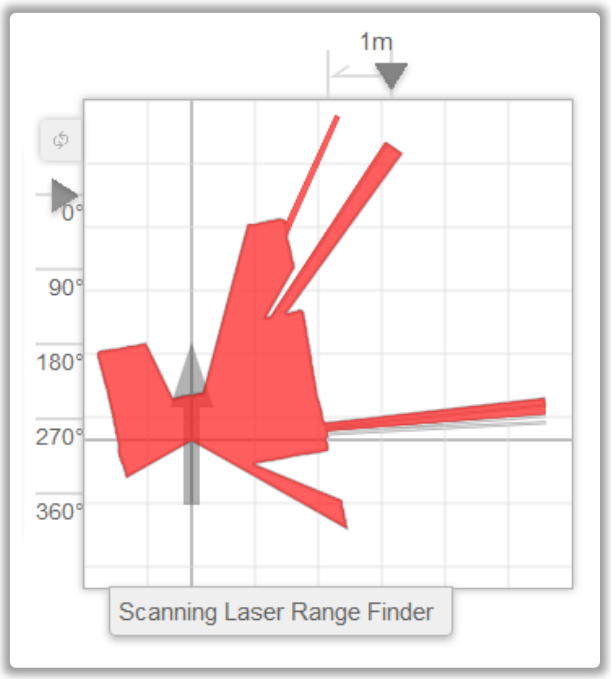
The discretisation of the commands comes from a maximum command time of 500 ms, however, there may be other sources of lag in the system - for example, internet latency, which is not-constant.

As a result of the non-constant latencies, the iRobot Create's movement may not be entirely repeatable – users should take care when navigating the maze to account for the inherent delays and variability of movements.

5.2.2 Laser Rangefinder Noise

When operating in manual mode or reviewing logged data – you may notice some outlying points in the laser rangefinder data. This is likely noise from the sensor.

Whilst the sensor is highly accurate – it is subject to noise and measurement variance like any sensor. Care should be taken not to interpret noise as a physical object (or lack of).

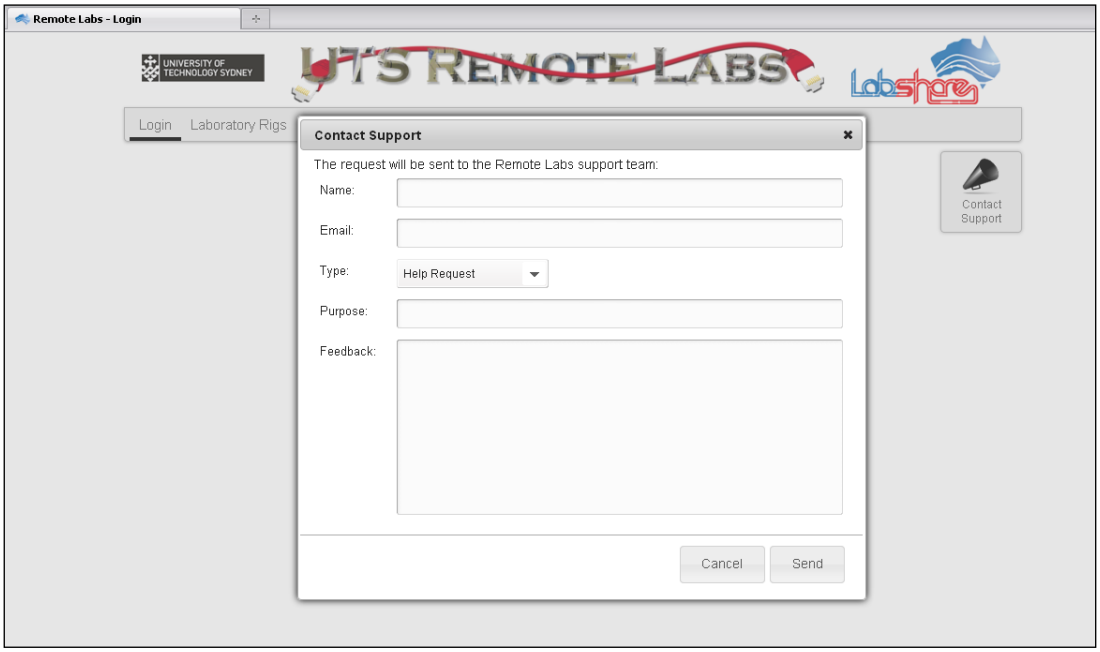


Above: A screen capture of laser rangefinder data showing noise.

5.3 Contacting Support

Any questions regarding the nature of assessment tasks should initially be directed to the relevant academic. If the user encounters any difficulties during the course of using the rigs, the **"Contact Support"** button should be used to request assistance and report an incident.

The following popup will appear – please enter your name and a valid email address, followed by a category from the "Type" drop down list.



You may then enter a brief statement regarding the nature of the request in the "Purpose" field. Be sure to enter as detailed a description as possible of the incident in the "Feedback" field.

5.3.1 Providing Feedback

Users are strongly encouraged to leave feedback and comments of their experience with the rigs to help improve the system, as well as any suggestions for additional features to be included in the future. Feedback can be left by clicking the **"Contact Support"** button and selecting "General comment" from the "Type" drop down list.